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Transparent Laser Ceramics at Lawrence Livermore National Laboratory (LLNL)

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TRANSPARENT LASER CERAMICS AT LAWRENCE LIVERMORE NATIONAL LABORATORY (LLNL)

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LLNL has been using the largest transparent laser ceramics for the last two years in the solid-state heat capacity laser (SSHCL). The lab is very interested in extending the use of transparent ceramics to other laser applications. In this talk we will discuss work at the laboratory aimed at better understanding the sintering and the criteria needed for good ceramic transparency, the application of transparent ceramics in the SSHCL laser and possible new applications of tailored ceramics.

We have been studying the vacuum sintering of high purity YAG, Nd:YAG and other powders prepared commercially by precipitation techniques, followed by dispersion and classification and also studying the sintering of powders prepared by flame-spray pyrolysis (FSP). Following sintering the microstructure closely resembles that predicted by a minimization of surface energy programs. However unlike the simulations typical sintered transparent ceramics have some small residual porosity, the pores being spherical and small compared to the size of the grains. The effect of this porosity on light scattering can be calculated using Mie scattering theory and criteria for pore size and density can be established. The reasons for the formation of these pores and their removal by hot-isostatic pressing (HIP) is discussed.

Our primary application of transparent ceramics has been for the amplifier slabs in the SSHCL. Our experience over the past two years has revealed some advantages over single crystals not commonly discussed. Thermal fracture, for example, has not been problem even when the slabs experienced rather large thermal gradients when they did not laze. Very little or no stress birefringence was observed at room temperature and very little during lasing. Mechanical stress failure occurred along grain boundaries in a path that relieved applied stress without branching.

Recently we designed slabs with integral Sm:YAG cladding to suppress amplified spontaneous emission. This approach was achieved by Konoshima through co-sintering. It has allowed us to edge-pump the slabs through the Sm:YAG greatly improving the beam quality and allowing us to achieve long run times. We now have several designs on the board for ~ 100 kW. Quasi-continuous operation is possible with the minimum number of laser diode running continuously. The amplifier slabs are swapped out of the laser beam after 5-10 seconds operation and cooled with cooling plates off-line.

Still further improvements in efficiency and thermal control will require materials with higher thermal conductivity and a smaller quantum defect, such as, ceramic Yb or Tm doped yttria or lutecia. Tailored ceramics may be used to grade dopant concentrations for still better beam quality, serve as light guides or wave guides, incorporate ASE suppression, or other multi-functionality. These applications will require even better control and mitigation of porosity.

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